Aug. 24, 1948. R. E. MUMMA ET AL 2,447,661

ELECTRON TUBE IMPULSE GENERATOR

Filed May 26, 1943 4 Sheets-Sheet 1

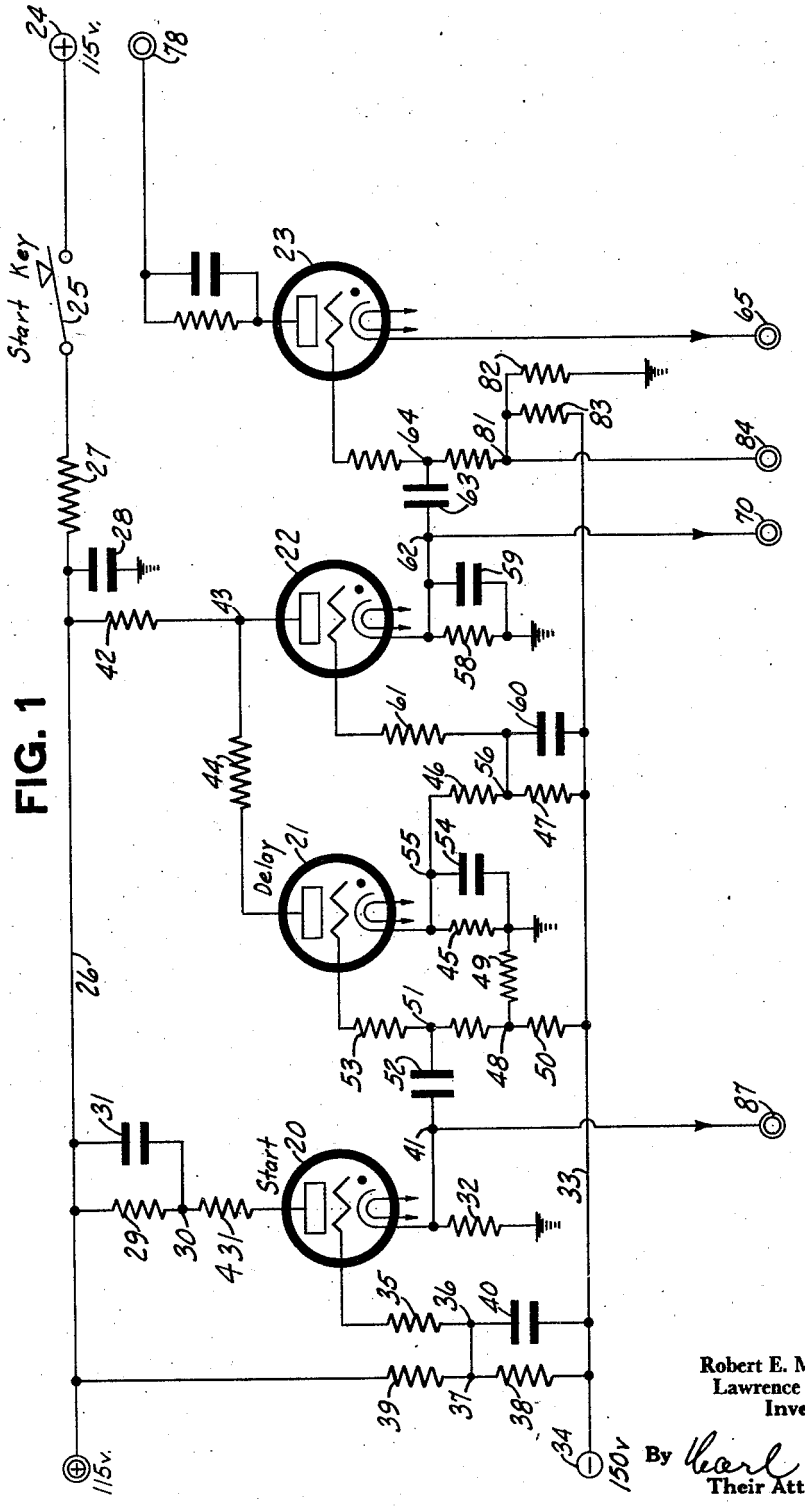

FIG. 1

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ELECTRON TUBE IMPULSE GENERATOR

Filed May 26, 1943 4 Sheets-Sheet 2

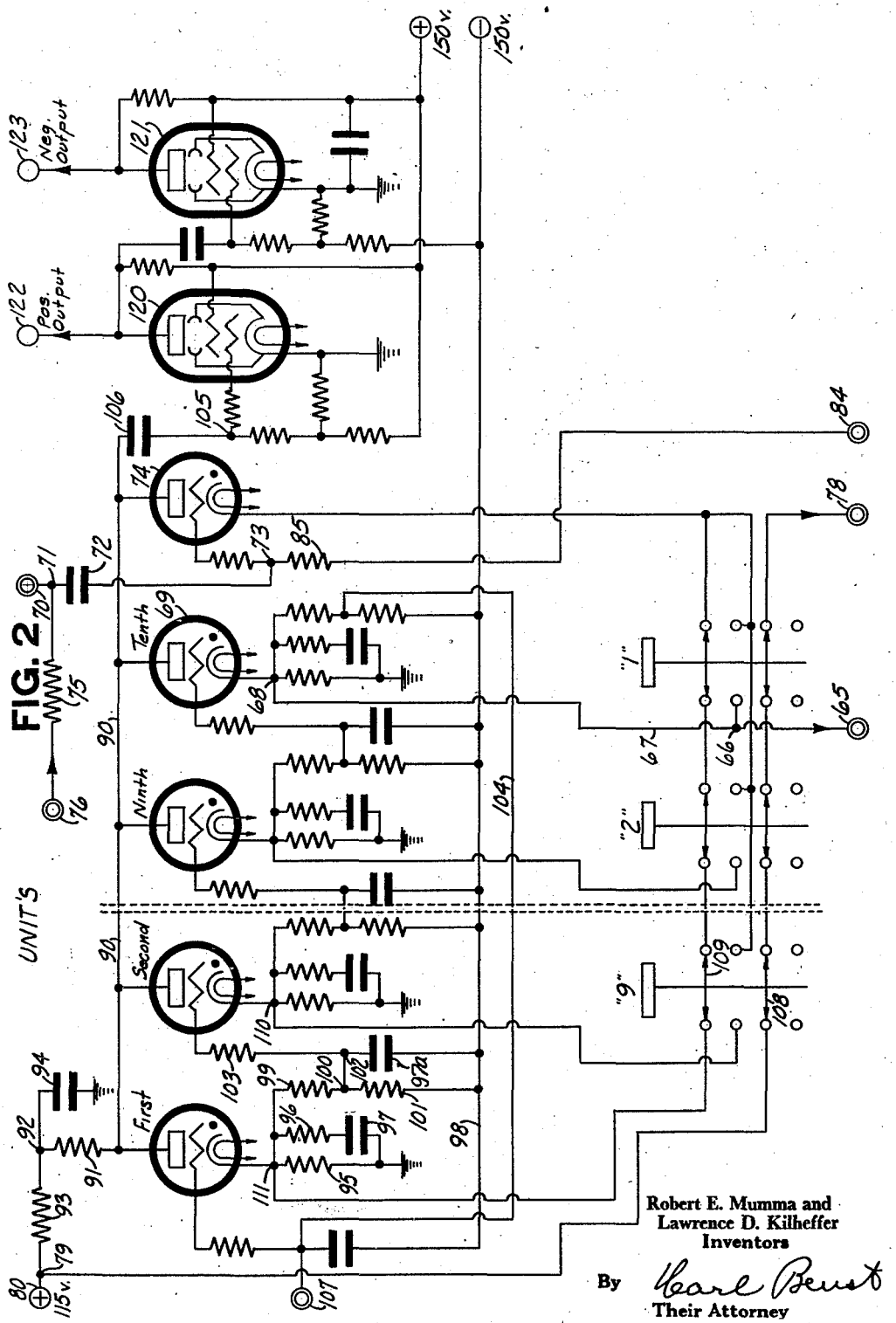

FIG. 2

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ELECTRON TUBE IMPULSE GENERATOR

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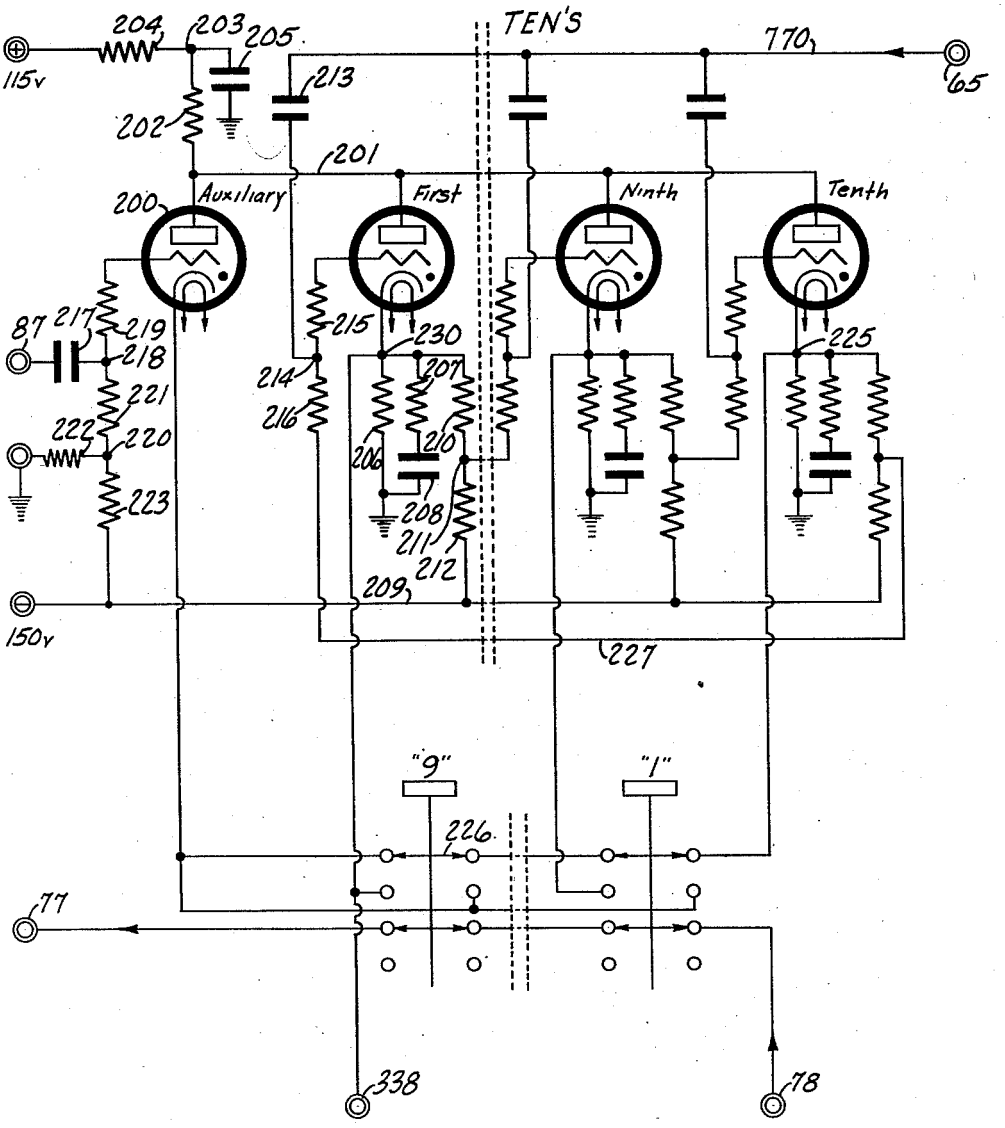
FIG. 3



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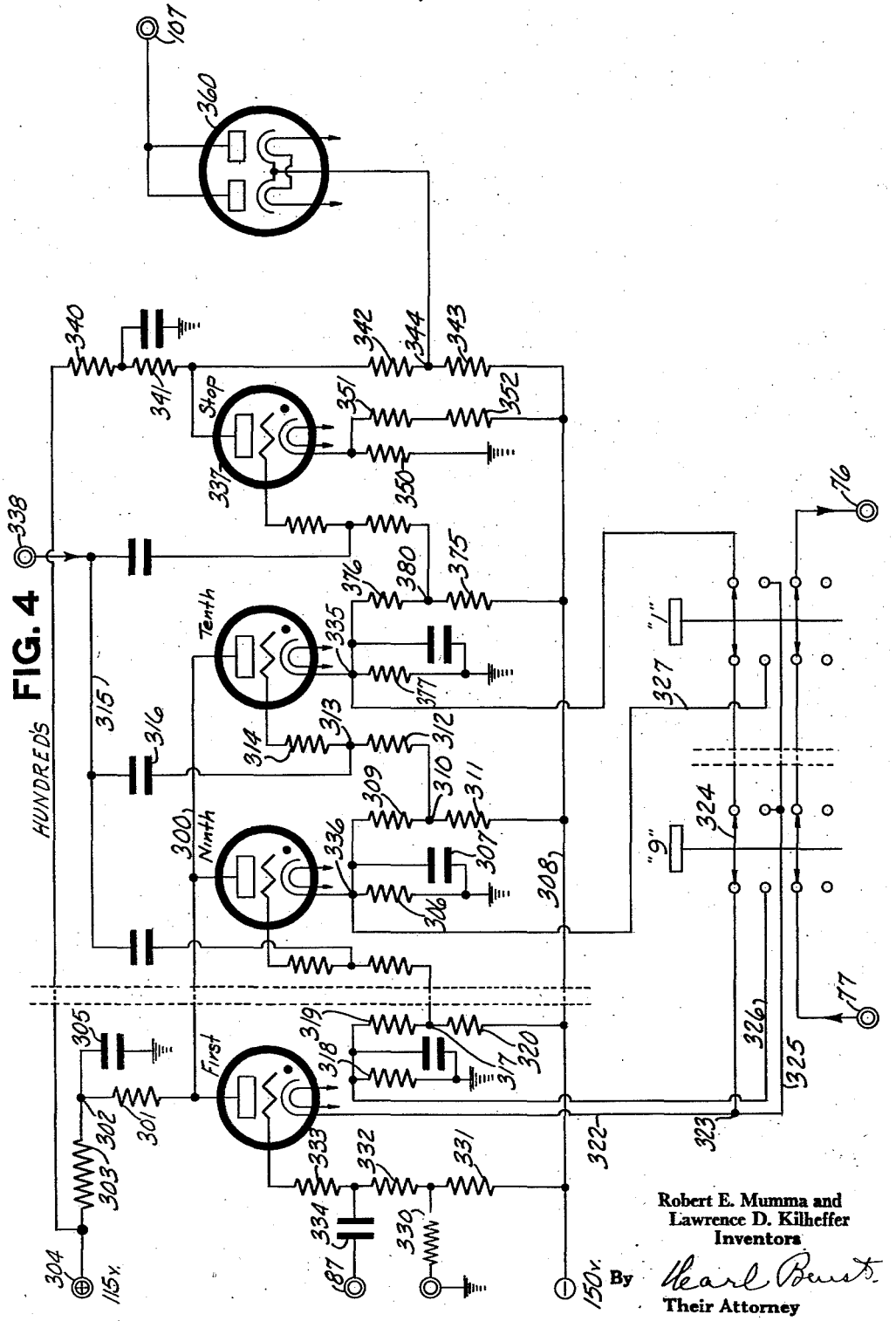
ELECTRON TUBE IMPULSE GENERATOR

Filed May 26, 1943 4 Sheets-Sheet 4

FIG. 4



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Patented Aug. 24, 1948

2,447,661

UNITED STATES PATENT OFFICE

2,447,661

ELECTRON TUBE IMPULSE GENERATOR

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Application May 26, 1943, Serial No. 488,496

15 Claims. (Cl. 315—230)

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This invention relates to an electronic electric impulse generator for generating a precise number of unit-representing impulses in a single burst under control of denominational key banks.

The impulses are each produced by the firing of one of a plurality of gaseous electron tubes arranged in an endless operative chain for serial and cyclic operation. The gaseous triodes used for an example are of the type having about a 16-volt anode-cathode voltage drop when conducting and requiring a controlling grid bias potential of about 12 volts negative with respect to the cathode. The number of full cycles, plus a partial cycle, if desired, the impulse-producing tubes operate determines the number of impulses generated. The tubes in the endless chain are fired one at a time in sequence repeatedly in cycles. A partial cycle is provided for to be gone through at the beginning of the operation to care for any odd number of impulses over that number in a full cycle or cycles that is required. The recycling is under control of said endless chain of impulse-producing tubes operating in conjunction with other groups of tubes to provide a selective control means which determines the number of tubes to operate in the partial cycle, if any, and to determine the number of full cycles.

The invention as disclosed, although producing impulses of unit value in a burst, has the selective feature based on three denominations of the decimal numerical notation. It will be evident, however, that any numerical notation and any number of denominations desired may be used in the construction of such a generator.

In general, the disclosure includes units, tens, and hundreds banks of selectively operable gaseous triodes, each bank under control of nine selectively operable key switches by which the number of impulses to be produced is chosen.

Operation of the keys presets certain tubes of each bank for operation. The tubes of the units bank of tubes are connected in an endless operative chain for firing one at a time in sequence automatically after once started, the endless chain operation beginning at a selected tube and continuing cyclically until the operation is stopped at a fixed tube in the chain. As each tube of the units bank fires, it produces an impulse which constitutes the output of the generator. The tubes of the tens bank of tubes are connected in an endless operative chain for firing step by step one at a time in sequence and cyclically, each step being in response to an impulse from the units bank transmitted once each cycle of the units bank. "Tens" keys are operated to determine at what tube in the tens bank the operation is to be commenced. The highest denominational bank, in this disclosure the hundreds bank, includes a group of gaseous triodes operated in a chain having a beginning point and an end. These tubes are operated step by step, each step being caused by an impulse produced each cycle of operation of the tens bank. The "hundreds" keys select that tube in the hundreds bank from which the operation commences. When the last tube of the hundreds chain is fired, the cycling of the units chain is stopped, and the operation is complete.

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Therefore, the principal object of the invention is to provide a novel electron tube electric impulse generator for producing a burst of electric impulses of unit value and of a precise selected number.

Another object of the invention is to provide an endless operative chain of electron tubes automatically firing one at a time in sequence, cyclically, under control as to the number of cycles.

Another object of the invention is to provide a plurality of groups of electron tubes, one of the groups being operable one at a time in endless chain sequence cyclically, and the other groups controlling the number of full cycles that said first group of tubes operates, as selectively predetermined.

Another object of the invention is to provide an endless operative chain of electron tubes operable automatically one at a time in sequence cyclically.

Another object of the invention is to provide an endless operative chain of electron tubes operable automatically one at a time in sequence, cyclically, from a selected beginning point.

Another object of the invention is to provide an endless chain of electron tubes rendered conducting automatically one at a time in sequence, cyclically, to generate an electric impulse on a common output circuit each time a tube becomes conducting.

Another object of the invention is to provide denominational banks of electron tubes, the tubes of the lowest bank being automatically rendered conducting in endless chain sequence step by step, one at a time, cyclically, said cycles being counted and selectively determined in number by operation of the higher denominational banks of tubes.

Another object of the invention is to provide a plurality of denominational groups of electron tubes, the tubes of one group being operated sequentially to produce impulses and cyclically to

operate the other groups as a multi-denominational counter to control the number of cycles of said one group.

With these and incidental objects in view, the invention includes certain novel features of construction and combinations of elements, the essentials of which are set forth in appended claims and a preferred form or embodiment of which is hereinafter described with reference to the drawings which accompany and form a part of this specification.

Of said drawings:

Fig. 1 is a circuit diagram of the operation-initiating electron tubes.

Fig. 2 is a circuit diagram of the units bank of the impulse generator and the output impulse power tubes, with a middle portion of the bank omitted.

Fig. 3 is a circuit diagram of the tens bank of the impulse generator, with a middle portion of the bank omitted.

Fig. 4 is a circuit diagram of the hundreds bank of the impulse generator, with a middle portion of the bank omitted.

Initiation of an Operation

The initiation of an operation is caused by the firing of certain of four grid-controlled electron gas discharge tubes in a certain order automatically. These four tubes **20**, **21**, **22**, and **23** (Fig. 1) receive their anode potential from a 115-volt positive potential supply terminal **24**, which, when switch **25** is closed, energizes conductor **26** through a 100-ohm resistor **27**. Capacitor **28** of .25 microfarad, coupling conductor **26** to ground, prevents shock application of potential to conductor **26**. Starting tube **20** receives its anode potential from conductor **26** through resistor **29** of 100,000 ohms, point **30**, and resistor **431** of 5,000 ohms. Point **30** is coupled to conductor **26** by a capacitor **31** of .0005 microfarad to provide an initial high current as tube **20** fires and becomes conducting. The cathode of tube **20** is connected to ground through resistor **32** of 25,000 ohms. The grid of tube **20** is connected to conductor **33** supplied with 150 volts negative potential, from source **34**, through resistor **35** of 500,000 ohms, points **36** and **37**, and resistor **38** of 1.5 megohms, which makes the grid highly negative before switch **25** is closed. Point **37** is connected to conductor **26** through resistor **39** of 1 megohm, and point **36** is coupled to negative 150 volt conductor **33** through capacitor **40** of .02 microfarad. Consequently, when switch **25** is closed, capacitor **31** becomes charged before the larger capacitor **40**, and finally, as the point **36** becomes more and more positive, tube **20** fires, and the momentary high current through the tube due to capacitor **31** causes the cathode to deliver, due to cathode resistance **32**, a sharp positive impulse at point **41**. This impulse fires a tube **21**, the firing time of which is used for delay purposes. Tube **21** receives its anode potential from conductor **26** through resistor **42** of 1,000 ohms, point **43**, and resistor **44** of 1,000 ohms.

The cathode of tube **21** is coupled to ground through resistor **45** of 25,000 ohms in parallel with capacitor **54** of .004 microfarad and is connected to negative supply conductor **33** through resistor **46** of 50,000 ohms and resistor **47** of 120,000 ohms, giving the cathode a normal potential of about 19 volts negative. Point **48**, which determines the normal potential of the grid of tube **21**, is connected to ground by resistor **49** of 40,000 ohms and is connected to the negative conductor **33** through resistor **50** of 100,000 ohms, giving point **48** a normal potential of about **43** volts negative, which will maintain tube **21** nonconducting until point **51** receives the positive impulse from point **41** through coupling capacitor **52** of .00005 microfarad, which fires tube **21**. Grid resistor **53** is of 5,000 ohms. After delay capacitor **54** is charged as tube **21** becomes conducting, point **55** rises in potential, due to the effect of resistor **45**, which rise in potential is reflected at point **56**, which determines the grid potential of tube **22**.

Tube **22** receives its anode potential from point **43**, before described. Its cathode is grounded through resistor **58** of 50,000 ohms in parallel with capacitor **59** of .001 microfarad. The grid of tube **22** is at the normal potential of point **56**, which is made about 57 volts negative. Thus, tube **22** is held from firing until its grid potential is raised by the firing of tube **21** and its continued conduction until delay capacitor **60** of .004 microfarad is charged. Grid resistor **61** is of 500,000 ohms. As tube **22** fires, a sharp positive potential impulse is produced at point **62** after delay capacitor **59** of .001 microfarad is charged. The impulse at point **62** is conveyed through capacitor **63** of .00005 microfarad to point **64** to fire tube **23**, which may or may not fire according to whether an extra unit is to be entered in the tens order of the impulse generator.

The cathode of tube **23** obtains its potential through point **65** (see also Fig. 2), point **66**, conductor **67**, and point **68**, which is the cathode supply point for tube **69** in the units bank Conduction in tube **23** (Fig. 1) will therefore cause a change in the potential of point **68** (Fig. 2) just as though tube **69** were conducting. This rise in potential of point **68** is to be observed later in connection with the description of the entry of the extra unit. Point **68** (Fig. 2) is also connected through terminal point **65** to the input conductor **770** (Fig. 3) of the tens order of the impulse generator for entering an extra unit into the tens order, as will be explained.

Point **62** is also coupled through terminal **70** (Figs. 1 and 2), point **71** (Fig. 2), and capacitor **72** of .00005 microfarad to grid point **73**, the change in potential of which fires tube **74** whenever tube **22** (Fig. 1) fires. Point **71** (Fig. 2) is given a normal positive potential by being connected through resistor **75** of 50,000 ohms, point **76** (see also Fig. 4), the lower key switches of the hundreds key bank, point **77** (see also Fig. 3), the lower key switches of the tens key bank, point **78** (see also Fig. 2), and the lower key switches of the units key bank to point **79**, which connects to the 115-volt positive supply source **80**. So, when no key is operated in any bank, the cathode of tube **22** (Fig. 1) is held so positive that it will not fire, thus preventing impulses from being anomalousy generated. The depression of any key will remove the positive potential from the cathode of tube **22**.

The normal grid bias of tube **23** (Fig. 1) is obtained from point **81**, which is connected to ground through resistor **82** of 30,000 ohms and connected to the 150-volt negative conductor **33** through resistor **83** of 100,000 ohms, thus giving the said point **81** and the grid a resultant negative potential of about 34 volts with respect to the cathode. The normal grid bias of tube **74** (Fig. 2) is also obtained from point **81** (Fig. 1) through terminal point **84** (see also Fig. 2), resistor **85** of 250,000 ohms, and point **73**.

Thus, tubes **20**, **21**, **22** and **23** fire in succession

when starting key switch 25 is closed, except that, when no denominational key is depressed, only tubes 20 and 21 are fired, and except when a key is operated in the units bank, in which event only tubes 20, 21, and 22 are fired, since, as later explained, tube 23 is deprived of anode potential when a key is depressed in the units bank.

The positive impulse which appears on terminal 87 (Fig. 1) as tube 20 fires is used to prepare the tens and hundreds banks of the device for operation, it being obviously necessary to have these banks ready before the operation of the units bank begins. The positive potential impulse on terminal point 70, as tube 22 fires, initiates the operation in the units bank. The current flow through point 65 causes the entering of an extra unit of data into the device when and where necessary.

The units bank

The units bank of the device includes eleven gaseous triode electron tubes, one of which, tube 74, participates only in the initiation of the cyclic operation. The remaining ten of the tubes are connected in an automatic operative circuit whereby they are fired one at a time in sequence in an endless chain cycle. As any one of the eleven tubes is rendered conducting, an output impulse is generated, the total number of which output impulses being the end result of the operation of the device. The ten tubes will be designated by the terms "first," "second," "third," "fourth," "fifth," "sixth," "seventh," "eighth," "ninth," and "tenth," the tubes intermediate the "second" and the "ninth" not being shown, as they would only uselessly expand the circuit drawings with repeating patterns. The designations of the tubes in this units bank or the tens and hundreds bank are not necessarily digit values, but merely represent their order in the endless chain.

The anodes of the tubes of the endless chain and tube 74, constituting the units bank, receive a 115-volt positive supply by being commonly connected to conductor 90, which is connected through resistor 91 of 3,000 ohms, point 92, and resistor 93 of 300 ohms to supply terminal 80. Point 92 is coupled to ground by capacitor 94 of .1 microfarad, which absorbs shock applications of potential and stabilizes the potential of point 92.

The grid potential supply for tube 74 has already been explained, and the cathode of tube 74 obtains its potential from point 68 or other cathode point, such as points 110 and 111, according as whether or not a key in the units bank has been operated. The cathode of each tube of the endless chain is coupled to ground through a resistor of 15,000 ohms, like resistor 95, in parallel with a resistor of 1,000 ohms, like resistor 96, which is in series with a capacitor of .004 microfarad, like capacitor 97, and is coupled to 115-volt negative supply conductor 98 through a 150,000-ohm resistor, like resistor 99, a point, like point 100, and a 300,000-ohm resistor, like resistor 101. This gives the cathodes each a potential of about 4 volts negative when non-conducting. Points like point 100 have a normal potential, when the associated cathode is non-conducting, of about 41 volts negative and are connected to the control grid of the next succeeding tube of the chain, as through a point like 102 and a resistor of 500,000 ohms like resistor 103. The conductor 104 completes the coupling of the

"tenth" tube to the "first" tube to close the chain into an endless chain. As a tube of the endless chain of the units bank commences to conduct, the capacitor coupling its cathode to ground charges, preventing the immediate rise of its cathode potential due to the resistances in the cathode supply circuit. During the first interval of charging of the cathode-ground capacitor, the conductor 90 drops in potential to within about 22 volts of ground. Every other tube of the chain is connected to the anode supply conductor 90, and, if any tube is conducting, it will thereupon be extinguished, as its cathode-ground capacitor has therefore been charged, which maintains the cathode at high potential as the anode potential drops and overshoots such maintained potential of the cathode. Such extinguishing action is explained more fully in United States application for Letters Patent, Serial No. 395,995, filed May 31, 1941, by Robert E. Mumma, which issued June 4, 1946, as U. S. Patent No. 2,401,657.

As a tube of the endless chain of ten tubes in the units bank of the device becomes conducting and its cathode rises in potential after the cathode-ground capacitor is charged, the point corresponding to point 100 will rise in potential sufficiently to cause the grid of the succeeding tube of the chain to fire. Consequently, the tubes in the endless chain of tubes will be rendered conducting one at a time in sequence as long as the operation is not stopped. Negative impulses will be produced and conveyed to point 105, through capacitor 106 of .00025 microfarad, each time a tube of the chain becomes conducting. Conduction in tube 74 also causes an impulse at point 105.

The stopping of the operation of the endless chain of the units bank is done by impressing terminal 107 with a strong negative potential to prevent the "first" tube from being fired by the "tenth" tube, and, as an object of the invention is to provide means to produce a number of impulses precise to the unit, the endless chain operation must be begun at a selected tube and stop at a fixed point, which will cause the device to produce an exact number of impulses to represent the units order. To this end, selecting keys, operating switches, determine where in the chain the operation shall commence. Point 111 is the fixed point for stopping the endless chain operation. Each key is given a value characterization which tells the number of impulses that will be sent in a first partial cycle before the "first" tube is fired to start a full cycle, if such key is operated.

The keys are numbered "9," "8," "7," "6," "5," "4," "3," "2," and "1," the keys in the descending series between "9" and "2" not being shown for the reasons given before in connection with the intermediate tubes of the endless chain that are not shown.

As an example, if the "9" key of the units bank is operated, switch 108 moves to its lower contacts, breaking the connection from point 79 to point 78 (see also Fig. 1), thus depriving the extra unit tube 23 of anode potential, so that it cannot fire. Switch 109 moves to its lower contacts, breaking the normal connection between the cathode of tube 74 and the cathode of tube "first," and connects the cathode of tube 74 with the cathode of tube "second." As tube 22 (Fig. 1) fires after closing starting key switch 25, a positive impulse appears at point 70 (see also Fig. 2), which fires tube 74 to give the first output impulse on conductor 90. It will be ob-

served that the cathode of tube 74 receives its potential from the cathode of tube "second," due to the switching of switch 109 of the "9" key to the lower contacts. The effect on point 110 is to raise its potential as though the "second" tube were conducting, which results in the tubes "third," "fourth," "fifth," "sixth," "seventh," "eighth," "ninth," and "tenth" firing before the operation of the units bank can be stopped. It will be evident that nine impulses will have been produced after the firing of the "tenth" tube. In the same manner, operation under control of the "1" selecting key permits only tube 74 to fire before the operation of the units bank can be stopped by placing a stopping potential on terminal 107. As the "tenth" tube fires, the positive impulse appearing at point 68 is impressed through terminal 65 (see also Fig. 3) to the input conductor of the tens bank of the device, which is thereby operated a step at the completion of each full cycle or part cycle of the units bank.

In the event that no key is operated in the units bank, tube 74 first operates, and tube "second" is fired by the subsequent rise in potential at point 111. In addition, the extra unit tube 23 (Fig. 1) is supplied with anode potential, which causes it to fire simultaneously with tube 74 (Fig. 2), and, through connection of its cathode with the cathode of tube "tenth" of the units bank, the common point 65 leading to the input of the tens bank (Fig. 3) is given an extra impulse. Therefore, if no key is operated in the units bank, an extra impulse is supplied to the tens bank.

Power amplifier electron tube 120 (Fig. 2) is provided to amplify and convert the negative output impulses appearing at point 105 into positive impulses at terminal 122, and power amplifier electron tube 121 produces amplified negative impulses at terminal 123.

Thus, the odd units impulses, produced in the first partial cycle of the units chain of tubes, are selected by key switches characterized by a like number. Full cycles of the units bank give ten impulses each.

The tens bank

The tens bank (Fig. 3) of the device includes an auxiliary gaseous triode 200 and ten gaseous triodes connected in an endless counting ring operated step by step in response to impulses, one impulse causing one step of operation. There are shown in Fig. 3 only three tubes of the ten tubes—the "first," the "ninth," and the "tenth." Tubes "second," "third," "fourth," "fifth," "sixth," "seventh," and "eighth" are not shown for the same reasons given for deletion of some of the tubes of the units bank.

All of the tubes of the tens bank receive their anode potential of 115 volts positive from conductor 201 through 3,000-ohm resistor 202, point 203, and resistor 204 of 300 ohms. Capacitor 205 of .1 microfarad, coupling point 203 and ground, acts as a shock absorber and stabilizer in the application of potential to the tens bank. The cathode of each tube of the ring is connected to ground through a 15,000-ohm resistor, like resistor 206, in parallel with a resistor of 1,000 ohms, like resistor 207, in series with a capacitor of .004 microfarad, like capacitor 208, and is connected to the negative 150-volt conductor 209 through a resistor of 100,000 ohms, like resistor 210, a point, like point 211, and a resistor of 100,000 ohms, like resistor 212. Under these circumstances, a cathode is normally at about 10 volts negative when non-conducting. The potential of the associated grid is normally held at about 87 volts negative, thus holding the tube in non-conducting condition. The grid of each tube of the tens chain is capacitatively coupled to input conductor 770 and terminal 65 from the units bank through a capacitor of .0005 microfarad, like capacitor 213, a point like point 214, and a current-limiting resistor of 500,000 ohms, like resistor 215. Resistors corresponding to resistor 216 are of 500,000 ohms.

When tube 20 (Fig. 1) fires, a positive impulse is impressed through terminal 87 (see also Fig. 3) and capacitor 217 of .00005 microfarad to point 218, which is connected to the grid of auxiliary tube 200 through resistor 219 of 50,000 ohms. The grid of tube 200 is normally supplied with a potential of about 34 volts negative, being connected to point 220 through resistor 221 of 250,000 ohms, which point 220 is connected through resistor 222 of 30,000 ohms to ground and through resistor 223 to the 150-volt negative conductor 209. The cathode of tube 200, when no tens key is operated, takes its potential from point 225, which is 10 volts negative, or is given the same potential by being switched by the upper key switch when a tens key is operated, like, for instance, the "9" switch 226, to the cathode of the associated tube, which in the case of switch 226 is the "first" tube. Consequently, normally non-conducting tube 200 is caused to conduct at the commencement of an operation by the closing of switch 25 (Fig. 1) and the ensuing conduction in tube 20, which produces the positive pulse to fire tube 200 (Fig. 3). As tube 200 fires, it changes the cathode potential of the cathode to which its own cathode is connected, in a positive sense. Thus, if the "9" key were operated, point 230 of the cathode of the "first" tube would be caused to rise in potential, which rise would be transmitted in part to the grid of the "second" tube to bring said "second" tube's grid potential high enough so that a positive impulse impressed on input terminal 70 would fire the "second" tube. In the event that no key of the tens bank is operated, the "tenth" tube's cathode is raised in potential as tube 200 fires, and, on the receipt of the first input impulse, the "first" tube fires. This first impulse may come either from the firing of tube 23 (Fig. 1) or from the firing of units bank tube "tenth" of Fig. 2. The rise in potential of the cathode of the tens bank "tenth" tube as it fires is conveyed to the grid of the "first" tube by conductor 227 to complete the ring. Each time the "first" tube of the tens bank is fired, a positive potential impulse is sent through terminal 338 to the hundreds bank (Fig. 4) to operate it a step from its preset condition. The tens bank, then, operates a step for each impulse received on terminal 70 and transmits an impulse to the hundreds bank to operate it a step each time the cathode of the "first" tube of the tens bank rises in potential.

By operating a selected one of the digit keys "1" to "9" in the tens bank, it may be determined that the first cycle of the tens bank shall be less than a full cycle and by how many steps. Thus, if the "1" key were operated in the tens bank, the firing of tube 200 would cause the "tenth" tube grid to be primed to fire said tube on receipt of the first impulse on terminal 70, and, on receipt of the second impulse, the "first" tube would fire, sending a transfer impulse to the hundreds bank.

The hundreds bank

The hundreds bank (Fig. 4) of the device includes ten gaseous triodes interconnected into an operative chain in which the tubes are caused to fire one after another from a selected beginning point to an end point in the chain.

These tubes are designated in Fig. 4 as "first" . . . "ninth," and "tenth," the intermediate tubes "second," "third," "fourth," "fifth," 'sixth," "seventh," and "eighth" not being shown for the same reasons stated in connection with similar deletions in the other banks previously described.

The ten tubes of the chain are given 115 volts positive anode potential through conductor **300**, resistor **301** of 4,000 ohms, point **302**, and resistor **303** of 300 ohms, which is connected to the 115-volt positive supply terminal **304**. Point **302** is coupled to ground through shock-absorbing and stabilizing capacitor **305** of .1 microfarad.

The cathodes of each of the tubes of the chain, except the "first" tube, are connected to ground through a 15,000-ohm resistor, like resistor **306**, in parallel with a capacitor of .004 microfarad, like capacitor **307**, and are connected to the negative 150-volt potential supply conductor **308** through a resistor of 100,000 ohms, like resistor **309**, a point, like point **310**, and a resistor of 100,000 ohms, like resistor **311**. Points like point **310** are connected through a resistor of 500,000 ohms, like resistor **312**, a point, like point **313**, and a resistor of 50,000 ohms, like resistor **314**, to the grid of the tube of the series having the next higher designation. Each point corresponding to point **313** is connected to impulse input conductor **315**, energized from the tens bank, through a .00005-microfarad capacitor, like capacitor **316**. The "second" tube grid (not shown) is supplied with biasing potential through a point **317**, which obtains its potential from the potential-dividing resistances **318**, **319**, and **320**, which are of the same values, respectively, as resistances **306**, **309**, and **311**.

The cathode of the "first" tube of the hundreds bank is normally connected by means of conductor **322**, point **323**, and closed switches of the upper key switches, like switch **324**, when no key is operated, to the cathode of the "tenth" tube. However, as a key, like "9," is operated, the upper switch **324** breaks the connection to the cathode of the "tenth" tube and establishes it by way of conductor **325**, lowered switch **324**, and conductor **326**, through resistor **319** to priming point **317** leading to the grid of the "second" tube (not shown). Operation of the "1" key instead of the "9" key connects the cathode of the "first" tube by way of conductors **325** and **327** to the cathode of the "ninth" tube. Thus, when the operation of the hundreds bank is commenced by a positive impulse impressed on terminal **87** (see also Fig. 1) as tube **20** fires, the "first" tube (Fig. 4) of the hundreds bank becomes conducting, and, by reason of the switching connections, just explained, when a key is operated, the cathode supply of said "first" tube is obtained from the cathode of one of the other tubes of the chain. Conduction in the "first" tube is equivalent to conduction in the tube to whose cathode it is connected, as far as it affects the priming for the next tube.

The normal non-conducting potential of the said "first" tube cathode is about 10 volts negative, and the grid is given a normal potential of about 57 volts negative by reason of being connected to ground through 30,000-ohm resistor **330**, and being connected to the negative 150-volt supply conductor **308** through resistor **331** of 100,000 ohms. Resistors **332** and **333** are, respectively, of 250,000 ohms and 50,000 ohms. This grid potential holds said "first" tube non-conducting until the starting impulse is received at terminal **87**, which is conveyed through capacitor **334** of .0005 microfarad and resistor **333** to fire said "first" tube. If no key is depressed, the firing of said "first" tube acts on point **335** just as though the "tenth" tube had fired. If the "one" key is depressed, the firing of the first tube acts on point **336** as though the "ninth" tube had fired, priming the grid of the "tenth" tube, and so on, the operation of the "9" key causing a potential rise at the grid point **317** of the "second" tube.

The operation of the device is stopped by the firing of a "stop" tube **337**, which is fired by the first impulse received from the tens bank after point **335** has risen in potential due either to conduction in tube "tenth" or conduction in tube "first" when no key is operated.

Therefore, when no key is operated in the hundreds order, the first impulse received from the tens bank through terminal **338** stops the generation of impulses, in a manner to be explained. If the "1" key of the hundreds bank is operated, the generation of impulses will be stopped on the second impulse conductor **315** received from the tens bank.

The chain-connected tubes of the hundreds bank are rendered conducting one at a time, as the firing of any tube in the chain extinguishes any other conducting tube therein because of the momentary dip in the potential of anode supply conductor **300** as a tube, supplied thereby, fires.

Termination of operation

Stop tube **337** receives its anode supply through resistors **340** and **341** of 300 ohms and 10,000 ohms, respectively, connecting it to the 115-volt positive conductor **308**, and through resistors **342** and **343** of 75,000 ohms and 120,000 ohms, respectively, connecting it to the negative supply conductor **308**. This gives the anode of tube **337** a normal anode supply of about 103 volts positive and gives point **344** a normal potential of about 5 volts positive. The cathode of tube **337** is normally about 10 volts negative, resistor **350** being of 3,000 ohms and resistors **351** and **352** totaling 40,000 ohms. The grid of the "stop" tube is normally kept at about 80 volts negative by being connected at point **380** to the negative supply conductor **308** through resistor **375** of 100,000 ohms, and connected to ground through resistor **376** of 100,000 ohms and resistor **377** of 15,000 ohms.

Therefore, when tube "tenth" is conducting (or tube "first" is conducting and no key is depressed), which condition primes the grid of tube **337** to be responsive to the next impulse from the tens bank and such impulse is received, tube **337** will fire and cause point **344**, normally maintained at about 12 volts, to drop sharply in potential, which drop is impressed through rectifier **360**, as has been said, on terminal **107** (see also Fig. 2), stopping the recycling of the units bank. Tube **337** is extinguished by the opening of starting switch **25** (Fig. 1).

Rectifier tube **360** (Fig. 4) is placed in series between point **344** and terminal **107** to permit a negative change in potential to be conveyed to the "first" tube of the units bank, but isolates its

grid from a positive change in potential of the cathode of tube 337 (Fig. 4).

Operation

Let it be supposed that one hundred and sixty-one impulses are to be produced. The "1" key in the units bank, the "6" key in the tens bank, and the "1" key in the hundreds bank are operated, and the switch 25 (Fig. 1) is closed. The hundreds bank "first" tube (Fig. 4) is fired, which raises the potential of point 336; the tens bank "fourth" tube cathode is raised in potential at the same time by the firing of tube 200 (Fig. 3) and, later, the cathode of the "tenth" tube 69 (Fig. 2) is raised in potential due to the firing of tube 74. The cathode impulse from tube 74 is also conveyed to terminal 65 (see also Fig. 3) by the switching of the "1" key to fire the "fifth" tube in the tens bank. At this point, one impulse has been generated at point 105 (Fig. 2). The "first" tube of the units bank then fires, and the first full cycle of the units bank is begun, which cycle, when completed, has produced ten more impulses and a transfer impulse to the tens bank to fire the "sixth" tube therein. The units bank cycles five more times, producing fifty more impulses, or a total of sixty-one impulses, before the "first" tube of the tens bank is fired, sending an impulse to terminal 338 (Figs. 3 and 4) to fire the "tenth" tube in the hundreds bank. The units bank recycles ten more times, causing ten transfers to the tens bank and one transfer to the hundreds bank to fire the stop tube. This produces a total of one hundred and sixty-one impulses.

Supposing, in the example, only one hundred and sixty impulses were desired. The hundreds and tens banks would be preset as before, but in the units bank, as no key is operated, point 111 (Fig. 2) receives the rise in potential, firing the "second" tube to start a complete cycle immediately. Tube 74 firing takes the place of the "first" tube firing in such first complete cycle. As no key is operated in the units bank, tube 23 (Fig. 1) fires and sends an impulse to the tens bank, as has been explained, at the same time tube 74 (Fig. 2) fires. When no key is operated in either the units bank or the tens bank, the impulse from tube 23 (Fig. 1) fires the "first" tube of the tens bank, which transfers one impulse to the hundreds bank.

It is apparent that the banks may be increased in number by adding intermediate banks similar to that shown in Fig. 3. It is also apparent that the banks themselves may vary; thus the first bank might be on a base of ten digits and the second bank on a base of five digits. The invention contemplates such variations.

It should be explained that timing capacitors, like capacitor 97*a* (Fig. 2), each of .002 micro-microfarad, connect the grid of each tube of the units bank to the 150 volt negative conductor 98, to provide a time interval between the firing of each two adjacent tubes in the units bank, to make that bank operate slower than the tens and hundreds banks. This is to provide a time interval long enough to create and apply a stopping impulse to point 107, when that condition of the device is reached, without any danger of an extra unwanted cycle of the units order bank. With circuit elements of the value given, the units bank operates at 3000 to 4000 steps per minute and the tens and hundreds banks operate at about 200,000 steps per minute. There is, therefore, time for a great number of tubes to operate in the higher orders to bring about the stopping potential, while the "first" tube in the units order is getting ready to fire. Although there is enough of a safety factor in the device, adjusted as disclosed, to accommodate any commercially desirable number of denominational orders without danger of an anomalous units cycle, it will be apparent that the size of the timing capacitors, like capacitor 97*a*, may be increased to still further slow down the units bank, if it is desirable or necessary.

While the form of the invention herein shown and described is admirably adapted to fulfill the objects primarily stated, it is to be understood that it is not intended to confine the invention to the form or embodiment herein disclosed, for it is susceptible of embodiment in various forms all coming within the scope of the claims which follow.

What is claimed is:

1. In combination, means including a plurality of gaseous discharge electron tubes, including a designated tube, connected in an endless operative chain circuit wherein they automatically become conducting one at a time serially in cycles and produce an electric impulse as each tube is rendered conducting; means to start an operation at a selected tube in the endless chain cycle; and automatic means to stop such operation after a selected counted number of cycles measured from the designated tube.

2. In combination, an electric impulse generator which, when started, continuously produces a plurality of like impulses in each of recurring cycles, each cycle being indicated by a cyclic impulse; means to count the cyclic impulses up to a selected number; means to start the generator at a selected point in a cycle; and automatic means to stop the generator when said selected counted number of cyclic impulses has been counted.

3. In combination, an electric impulse generator including a plurality of electron tubes rendered conducting one at a time serially in an endless chain having recurrent cycles of operation, the act of a tube being rendered conducting causing an electric impulse; a selective key controlled device for initiating the operation of the generator with any tube of the chain; a second plurality of electron tubes rendered conducting serially, one step of serial operation being caused at the end of each cycle or part cycle of operation of the impulse geenrator; and means rendered effective at the end of a compete operation of said second plurality of tubes for stopping the cyclic operation of the impulse generator.

4. In combination, an electric impulse generator including a plurality of electron tubes rendered conducting one at a time serially in an endless chain having recurrent cycles of operation, the act of a tube being rendered conducting causing an electric impulse; a selective key controlled device for initiating the operation of the generator with any tube of the chain; a second plurality of electron tubes rendered conducting serially, one step of serial operation being caused at the end of each cycle or part cycle of operation of the impulse generator; means rendered effective at the end of a complete operation of said second plurality of tubes for stopping the cyclic operation of the impulse generator; and selectively operable means for starting the operation of said second plurality of tubes at a selected place in a complete operation of the tubes

so as to accurately determine the number of complete cycles of operation which shall be performed by the first group of tubes.

5. A self-operating ring of electron tubes wherein the tubes are rendered conducting one at a time in endless chain repeating cycles; and a second operative ring of electron tubes arranged in an endless chain operating circuit wherein the tubes are caused to be rendered conducting step by step one at a time in endless chain repeating cycles, one step of operation being caused by the completion of a cycle of the self-operating ring.

6. A self-operating ring of electron tubes wherein the tubes are rendered conducting one at a time in endless chain repeating cycles; a second operative ring of electron tubes arranged in an endless chain operating circuit wherein the tubes are caused to be rendered conducting step by step one at a time in endless chain repeating cycles, one step of operation being caused by the completion of a cycle of the self-operating ring; and a third operative ring of electron tubes arranged in an ending chain circuit wherein the tubes are caused to be rendered conducting step by step one at a time, one step of operation being caused by the completion of a cycle of the second ring.

7. A self-operating ring of electron tubes wherein the tubes are rendered conducting one at a time in endless chain repeating cycles; a second operative ring of electron tubes arranged in an endless chain operating circuit wherein the tubes are caused to be rendered conducting step by step one at a time in endless chain repeating cycles, one step of operation being caused by the completion of a cycle of the self-operating ring; and selectively operable means to preset each ring to commence the cycle of each at a predetermined tube in the ring.

8. A plurality of gaseous electron tubes each having at least an anode, a cathode, and a control grid; circuits including a common resistance for supplying anode potential to said tubes; circuits including a resistance and capacitance in parallel for supplying cathode potential to each of said tubes; circuits for supplying normally controlling bias potential to the grids of said tubes, each of which grid circuits is also connected to the cathode of another tube to form an endless operative chain wherein, if one preceding tube is rendered conducting, the next succeeding tube of the chain is automatically rendered conducting and the preceding tube is extinguished, said anode supply means being given a potential surge when a tube commences conducting; selectively operable control means for stopping the endless chain operation at a fixed tube after a precise selected counted number of complete cycles of operation of said chain, considering said fixed tube as the end point of a cycle; and control means for starting operation of the device with any selected tube by causing it to conduct.

9. A plurality of electron tubes; means connecting the tubes in a circuit wherein they are rendered conducting one at a time in endless chain sequence automatically; means to select the tube with which the sequence is started; and electronic counting means to determine a counted number of complete chain sequences performed as reckoned from a fixed tube in the chain.

10. A plurality of electron tubes; means connecting the tubes to become conducting one at a time in an automatic endless chain sequence operation and to generate an electric impulse each time a tube becomes conducting and to generate a control electric impulse when a certain sequence end tube becomes conducting; means to count the control impulses; and means to automatically stop the chain sequence operation after a certain counted number of control impulses have been counted.

11. In combination, a first plurality of gaseous electron tubes, each having at least an anode, a cathode, and a control grid; means including a common resistance in a common potential supply oconductor supplying anode potential to the anodes of said tubes; means for supplying cathode potential to said tubes including a resistance and capacitance in parallel for each cathode supply; means supplying normally controlling potential bias to each grid; means connecting the tubes in an endless operative chain cathode to grid, the potential supply, resistances, and capacitances being so balanced that, if any one tube is fired and rendered conducting by lowering its potential grid bias, the succeeding tube in the chain will fire and the tubes will automatically become conducting one at a time in sequence cyclically and each of the tubes, when commencing to conduct, causing a potential drop in said common anode supply conductor; an auxiliary gaseous electron tube having at least an anode, a cathode, and a control grid, whose anode is connected to the common anode supply conductor, whose cathode is selectively connectable to the cathode of any tube of the ring, and whose grid is normally given a controlling potential bias; means to relieve the grid bias on said auxiliary tube to fire it and render it conducting; a second plurality of gaseous electron tubes, each having at least an anode, a cathode, and a control grid; means including a common resistance in a common potential supply conductor supplying anode potential to said second plurality of tubes; means supplying cathode potential to said second plurality of tubes, including a resistance and capacitance in parallel for each cathode supply; means supplying normally controlling potential bias to each grid of the second plurality of tubes; means connecting the second plurality of tubes in an endless operative chain cathode to grid, the potential supply, resistances, and capacitances associated with said second pluraltiy of tubes being so balanced that, if one tube be rendered conducting, it will lower the potential bias on the grid of the next succeeding tube of the chain to a point where it is appreciably nearer the firing point than any other tube of the chain; means electrostatically coupling the grid of each tube to the cathode of one of the tubes of the first-mentioned plurality of tubes; a third plurality of gaseous electron tubes, each having at least an anode, a cathode, and a control grid, and having anode, cathode, and grid bias potential supply means similar to said second plurality of tubes and having operative connections between the cathode of one tube and the grid of a succeeding tube in an ending chain from a beginning tube; means capacitatively coupling all the grids of said third plurality of tubes, except the beginning tube, to the cathode of a tube of the second plurality; means to select for firing one of the tubes of the third plurality as a precedent to the firing of the auxiliary tube of the first plurality of tubes; and means operated by the conduction in the last tube of the chain of the third plurality of tubes to place a controlling potential bias on

the grid of one of the tubes of the first plurality of tubes to stop the endless operation of said first plurality of tubes.

12. In combination, a plurality of two or more electron tubes; means for supplying operating electric potential to said tubes; means connecting the tubes in an endless operative chain in which they become conducting one at a time in sequence automatically over and over; and a conductor common to all the tubes which is given an electric impulse as a consequence of each tube operation.

13. In combination, a plurality of electron tubes connected in a circuit so that they become conducting one at a time in an endless operative chain automatically; selective means to determine what tube in said chain shall be the first to become conducting; and electronic means operable to stop said endless chain operation at a fixed place in the chain.

14. In combination, a recycling electronic electric impulse producer producing a fixed number of impulses each complete cycle; selective means operable to cause a partial first cycle producing a number of impulses less than the fixed number, after which full cycles of operation are performed; and an electronic counter preset to stop said impulse producer after a selected number of cycles in addition to any selected partial cycle.

15. In combination, a plurality of gaseous electron tubes each having at least an anode, a cathode, and a control grid; means including a common ressitance in a common potential supply conductor supplying anode potential to the anodes of said tubes; means for supplying cathode potential to said tubes including a resistance and capacitance in parallel for each cathode supply; means supplying normally controlling potential bias to each grid; means connecting the tubes in an endless operative chain cathode to grid, the potential supply, resistances, and capacitances being so balanced that, if any one tube is fired and rendered conducting by lowering its potential grid bias, the succeeding tube in the chain will fire and the tubes will automatically become conducting one at a time in sequence cyclically and each of the tubes, when commencing to conduct, causing a potential drop in said common anode supply conductor; an auxiliary gaseous electron tube having at least an anode, a cathode, and a control grid, whose anode is connected to the common anode supply conductor, whose cathode is selectively connectable to the cathode of any tube of the ring, and whose grid is normally given a controlling potential bias; and means to relieve the grid bias on said auxiliary tube to fire it and render it conducting.

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